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Research Paper

Minimising soil disturbance and reaction forces for high speed sowing using bentleg furrow openers

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Australian no-till farmers often use narrow point openers to create furrows for seed and fertilizer placement. However, operational speeds are limited due to excessive lateral soil throw reducing furrow backfill and causing interactions between adjacent furrows. This study measured the effects of speed (8, 12 and 16 km h^{-1}) on soil disturbance and tillage forces for five different openers, aiming to evaluate suitable options for high speed seeding. Three straight shank openers, 90° (blunt and chamfered face) and 53° rake angles were compared to two bentleg geometries (45 and 95 mm offsets), in a dry silt-loam field soil. The 53° straight opener showed the largest response to speed, reducing furrow backfill and increasing lateral soil throw (from furrow center). The addition of a double sided chamfer reduced lateral soil throw and maintained 100% backfill at 8 km h^{-1} but soil disturbance increased at 12 and 16 km h^{-1}. Both bentleg openers maintained 100% backfill and operated with a lateral soil throw less than half the straight openers at 8 km h^{-1}. However, the 45 mm offset bentleg opener had more soil throw at speed. This resulted in reduced furrow backfill and increased lateral soil throw at 16 km h^{-1} (reaching similar to the straight shank openers). The 95 mm offset bentleg was able to maintain its low soil disturbance characteristics at speeds up to 16 km h^{-1}. The findings show potential for new opener technology to increase operating speeds of no-till seeding operations by minimising soil disturbance and draft, therefore improving work-rate and timeliness of sowing.

1. Introduction

No-till farming is a system which relies on placing seeds into undisturbed soil, where the furrow opener typically loosens a narrow slot of sufficient depth to obtain desired seed placement and soil coverage, with no other soil tillage operations. No-till seeding is often arbitrarily defined as a technique which must keep soil surface disturbance area below 50% (Derpsch et al., 2014), while the method of quantifying soil disturbance is often poorly described. A majority of Australian no-till seeding systems use narrow point openers to open the soil and place seed and fertiliser in the furrow. However, the maximum operating speed of these tine-style seeding systems is typically limited to 6–9 km h^{-1} due to the often excessive soil disturbance. Soil disturbance can be defined as

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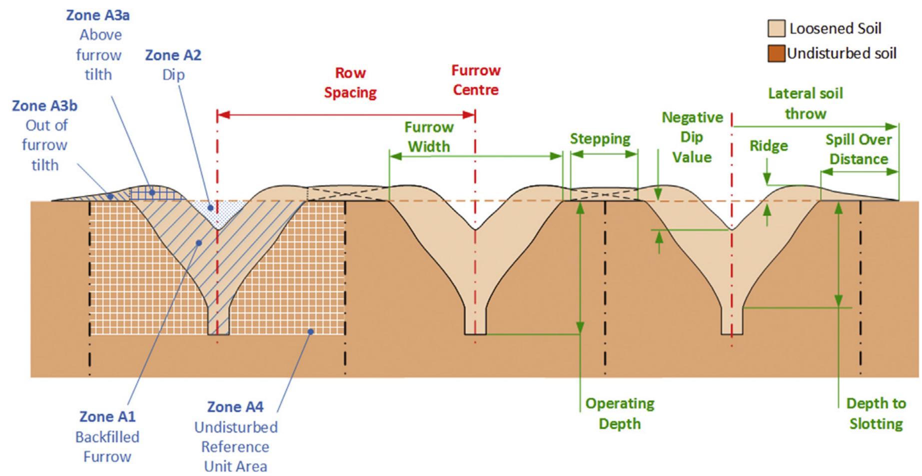

Fig. 1 – Defining soil disturbance parameters relevant to no-till narrow point openers.

the loosening (reduction in bulk density), movement (change in position along 3 dimensional directions) and mixing (relative exchange of positions, particularly in the vertical direction) of soil caused by an opener passing through soil. Although there are a number of generic parameters that describe aspects of soil disturbance – such as furrow cross-sectional area, furrow depth, forward, lateral, and vertical soil movement – in practice, two particularly important parameters describing soil disturbance in a no-till seeding context are (Fig. 1):

- The *lateral soil throw* (defined as the horizontal distance of effective reach of loosened soil, measured from the furrow center, perpendicular to the travel direction). A related but more sensitive assessment parameter is the spillover distance, which is the portion of lateral soil throw occurring beyond the furrow edges.
- The proportion of volumetric *furrow backfill* (defined as the proportion of furrow cross sectional area filled by loosened soil).

These two parameters are sensitive to the limitations of no-till seeding displayed at excessive speeds. In the Australian context, a faster operating speed with tine seeders is an attractive proposition which would enable growers to increase both work rate and timeliness of sowing and thus reduce labour costs. Faster operating speeds may also allow smaller implement widths to be used for similar or better work rates, therefore potentially reducing machinery costs and road transport widths.

Soil stepping occurs when lateral soil throw interacts between adjacent furrows. The extent of soil stepping is a function of the row spacing and lateral soil throw (as shown in Fig. 1). It is of particular concern when the lateral soil throw becomes equal to or greater than the row spacing (Desbiolles & Saunders, 2006; Hasimu & Chen, 2014). This situation results in unwanted additional soil cover over the neighbouring furrows (a process commonly known as 'furrow ridging'), thus increasing the depth of soil cover over the seed (Desbiolles & Kleeman, 2003). In many Australian farming systems, pre-emergence herbicides are often sprayed onto the soil surface prior to sowing and incorporated by the crop sowing operation to reduce volatilization losses, and photo-degradation, and thus improve chemical efficacy (Ashworth, Desbiolles, & Tola, 2010). These herbicides are typically non-selective and act on germinating seedlings. In this context, narrow points clear herbicide contaminated soil over the seed zone and may throw it onto adjacent seed rows, inhibiting their early crop development. Lateral soil throw has been shown to increase with greater operating speed for a range of openers (Desbiolles & Saunders, 2006), which in practice limits the acceptable operating speed of narrow point seeders. As soil stepping for a given soil-opener context is a function of row spacing. The issue of excessive lateral soil throw in practice contributes to limit the adoption of narrow row spacing, as an integrated weed management tool to increase crop competition (Ashworth et al., 2010).

In this study, the *furrow backfill* is defined on a volumetric basis as per Equation (1), and is an important parameter for no-till seeding systems as it quantifies the available loosened soil in the furrow to achieve the desired seed placement and coverage outcomes.

$$\textit{Furrow Backfill} = \frac{A1}{A1 + A2} \times 100\ [\%] \tag{1}$$

Where the A_1 and A_2 are defined in Fig. 1.

In the process of loosening, the furrow soil expands to an extent defined by the 'swell factor' (McKyes, 1985), and the amount of spillover soil throw (which can be assessed on a volumetric basis by the 'out of furrow tilth' parameter – Zone A3b, Fig. 1) dictates the 'furrow emptying' effect. By definition, Equation (1) cannot define furrow backfill beyond 100%, whereby any extra loosened soil (zone A3a, Fig. 1) above the reference furrow volume is not accounted for. The approach taken in this study is therefore focused on quantifying a furrow emptying outcome of tillage, against the reference furrow zone (A1+A2 defined in Fig. 1). While a gravimetric approach could more suitably track furrow backfill from the fullest to the lowest value, its measurement in the field is much more involved, and was not used in this study. As a complementary parameter to furrow backfill that was practical to measure in the field and did not truncate results at